Investigating Meaning in Learning: A Case Study of Adult Developmental Mathematics

Tim Glasser

San Francisco State University, CA, USA

tim_glasser@hotmail.com

Abstract

The objective of this article is to investigate meaning and relevance in the context of adult developmental math learning and instruction. In this case study, at the Art Institute of San Francisco, 12 vocational instructors and four math learners are interviewed on their early and current math experiences. During the semi-structured interviews, the adult math learners and vocational instructors reminisce on math in their learning and in their work. The interview transcripts are later analyzed for constructivist themes or codes.

From instructor interviews, there appears to be a strong correlation between instructor views of meaning and learning and constructivist principles. There is a weaker correlation of these themes with the views of the adult learners, and there is evidence these developmental learners show signs of cognitive overload on certain constructivist tasks. These adult developmental learners appear to derive mathematical meaning from behaviorist learning and instruction involving step by step processes, the linking previous concepts, and the repetition of key ideas. It may be that this is the way these informants learned math in the pre-constructivist days of mathematics instruction.

Introduction

The primary objective of this study is to find what is mathematically relevant to adult learners and vocational instructors at the focal site. The focal site in this case is the Art Institute of San Francisco (*Art Institute*), a privately owned vocational college.

A mathematically imaginative workforce is crucial because of advancing methods of production, especially the introduction of computer-based tools such as *Photoshop, Illustrator* and *AutoCAD*. Workers are less and less expected to carry out mindless, repetitive chores. Instead they are engaged actively in team problem-solving, talking with their co-workers and seeking mutually acceptable solutions (Bailey, 2001). Workers must ask the right questions, assimilate new information and solve unfamiliar problems in new ways.

Throughout their lives learners will need to be adaptable – to continue to explore the world, accommodate changing conditions and actively seek and create new knowledge. This need or flexibility implies that a mathematics education must emphasize a dynamic literacy that is centred on the problem being solved (Swan, 2005).

In the enlightened postcolonial period after 1945, anthropologists started to present interviews as scholarship using journalistic techniques (MacLeod, 1987/1995), rather than using the historically compromised scientific approach (Burawoy, 1991). Similarly, the ultimate objective of this study is not to just establish a relationship between two pre-ordained variables, but to use the instructor and adult learner insight into mathematics instruction and learning to help our learners and inform our instructors at the focal site (Duncan-Andrade,

1999). The interview data is being taken as a whole of the case and the interview data is triangulated with observations, student work. The data is also triangulated with the secondary indicators of learning outcomes such as the quantitative pass rates, persistence, average class grade and absences.

Literature Review

"Some learners find it pointless to do their mathematics homework; some like to do trigonometry, or enjoy discussions about mathematics in their classrooms. Some learners think that mathematics is useless outside school; other learners are told that because of their weakness in mathematics they cannot complete a Bachelor's degree. All these raise questions of meaning in mathematics education" (Kilpatrick, Hoyles, and Skovsmose, 2005b p.5). Meaning is used in a rather personal sense of the learner relating to relevance and personal significance. For example, "What is the point of this for me?" On the other hand, meaning can also be used in a rather objective way when describing "an agreed, common meaning within a community" (Kilpatrick et al., 2005b p.5).

We may claim that an activity has meaning as part of the curriculum, while students might feel that the same activity is totally devoid of meaning" (Kilpatrick et al., 2005b, p. 9). One can, however, even go a step further by saying that although a learner might think that a certain activity is totally devoid of objective meaning, the learner still sees a personal meaning in relation with the activity. This personal meaning, then, can be of different kinds. The first issue for meaning is that personal meaning is *subjective* and *individual*. This means that every person has to construct her or his own meaning with respect to a certain object. There is no given objective meaning; meaning cannot just be endowed. Also, as the construction of meaning is not collective but individual, different students sitting in the same lesson can also construct different meanings (Kilpatrick, Hoyles and Skovsmose, 2005a, p. 2).

To summarize, meaning can be reflected on and it can also be subconscious. This means that the process of meaning making can sometimes be dominant in the situation, so that as one is aware of what is going on; the meaning enters consciousness. Meaning does not have to be conscious but can be constructed sub-consciously, so that it is there without awareness. From a constructivist perspective, Kilpatrick states that the problem of construction of meaning itself is not really tackled. This is an evasive problem, because it is difficult to know what each partner (the learner and the teacher) thinks; we can only hypothesize this by interpreting what they do and say (Kilpatrick et al., 2005b p.19). Math has no implicit meaning. This implies that everyone has to construct his or her own personal meaning, so that it is probable that learners develop different kinds of meaning concerning the same mathematical task or problem.

Mathematics Learning

There is also a plethora of recent literature, which supports meaningful mathematics learning. The National Council of Teachers of Mathematics (NCTM) released a landmark document *Curriculum and Evaluation Standards for School Mathematics* (*The Standards*), which posits that increasing meaning in mathematics instruction, curriculum and assessment better prepares the learner for employment: The fastest growing jobs require much higher math, language and reasoning capabilities than current jobs, while slowly growing jobs require less (Cohen, 1995, p.7).

Clearly influenced by the foundational philosophies of constructivism and

incorporating elements of Knowles' (1980) concepts of adult centered learning, the *Standards* suggests all high school learners are capable of succeeding in mathematics, but courses must link-in and interweave the *Big Ideas* of mathematics. The *Big Ideas* include balance, number sense, proportional reasoning, variable, representation, measurement, relations and inductive and deductive reasoning. According to *The Standards*, these *Big Ideas* should be introduced as early as possible in the mathematics syllabus to allow learners to gain familiarity with these concepts of mathematics and ultimately to prepare the learners for subsequent and more advanced algebra courses.

Several assumptions shape the vision of *The Standards*. Firstly, mathematics is something a person does. Knowing mathematics means being able to use it in a purposeful way. To learn mathematics, learners must be engaged in exploring, conjecturing and thinking rather than the rote learning of rules and procedures. In other words, mathematics is not a spectator sport. When learners construct a personal knowledge derived from meaningful experiences, they are much more likely to retain what they have learned. This underlines the new role of the teacher in providing and explaining these experiences. Another assumption is that mathematics has a broad content encompassing many fields. Learners can benefit from exposure to a broad range of content that reveals the usefulness of mathematics. Through this exposure learners can build a foundation of relevance and meaning to their learning of mathematics. Another assumption of *The Standards* is that mathematics instruction can be improved through the appropriate use of evaluation. Evaluation should concentrate not only on assessing what the learners knows, but how they think and approach problems.

Crucially, according to *The Standards,* the teaching and learning focus should be on reasoning, rather than rote learning. The teacher of mathematics should orchestrate discourse by posing questions and tasks that elicit, engage, and challenge each learner's thinking. The teacher of mathematics should:

- Listen carefully to learners' ideas.
- Ask learners to clarify and justify their ideas orally and in writing.
- Identify, from among many ideas that learners bring up in a discussion, ideas to study in depth.
- Decide when and how to attach mathematical notation and language to learner's ideas.
- Decide when to provide information, when to clarify an issue, when to model, when to lead, and when to let a learner struggle with a difficulty.
- Monitor the learner's participation in discussions and deciding when and how to encourage each learner to participate.

The teacher of mathematics should promote classroom discourse in which learners;

- Listen to, respond to, and question the teacher and one another.
- Use a variety of tools to reason, make connections, solve problems, and communicate.
- Initiate problems and questions.
- Make conjectures and present solutions.

- Explore examples and counterexamples to investigate a conjecture.
- Convince themselves and one another of the validity of particular representations, solutions, conjectures, and answers.
- Rely on mathematical evidence and argument to determine validity.

Another seminal work in this area is *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus* (*Crossroads*) by the American Mathematical Association of Two Year Colleges. *Crossroads* has established goals and standards for preparation for college-level mathematics and is guided by these fundamental principles:

- All learners should grow in their knowledge of mathematics while attending college.
- Learners should study mathematics that is meaningful and relevant.
- Mathematics must be taught as a laboratory discipline.
- The use of technology is an essential part of an up-to-date curriculum.

Crossroads is highly influenced by *The Standards*, but is yet another highly influential work in its own right, because it is primarily directed to *adult* developmental mathematics. *Crossroads* reflects many of the same principles found in *The Standards*. These standards place emphasis on using technology as a tool and as an aid to instruction, developing general strategies for solving real-world problems, and being actively involved in the learning process. In particular, developmental math courses at the post-secondary level should include traditional topics, but should also incorporate technology and project-based learning.

Research Question

The research question addressed in this article is:

> Are the principles of constructivist math learning reflected in the math recollections of adult learners and vocational instructors at the *Art Institute*?

In the next section will describe the methodology used to answer this question.

Research Methodology

The research draws from participatory action research methods, (Kemmis, and McTaggart, 1988) which position the researcher simultaneously as a practitioner at the focal site where the study takes place, and also as a collaborator with the learners themselves with the aim of improving their own educational practices. The research goals of this research are as follows:

- The improvement of practice through continual learning and progressive problem solving.
- A deep understanding of practice and the development of meaningful mathematics learning.
- An improvement in developmental mathematical learning outcomes in the community of the *Art Institute*.

According to the above sources, participatory action research as a method is scientific in that it changes something and observes the effects through a systematic process of

examining the evidence. The results of this type of research are practical, relevant, and can inform theory.

The design of this case study is based on a seminal work by Yin, in that a single case study is used to confirm or challenge a theory, or to represent a revelatory or extreme case (Yin, 1994). In this instance, the case study at the *Art Institute* is ideal for a revelatory case study, as the researcher has access to a phenomenon that was previously inaccessible. For example, many developmental mathematics courses occur in the space of public education and are devoid of context and relevance, but at the *Art Institute* developmental mathematics is studied simultaneously with the learner's vocational degree and as such is ideal for a revelatory case study of meaning in mathematics.

Each individual case study consists of a whole study, in which facts are gathered from various sources and conclusions drawn on those facts. Consideration has been given to construct validity, both internal and external. Yin suggests using multiple sources of evidence as the way to ensure the construction of validity. He lists six sources of evidence for data collection in the case study protocol: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts.

Art Institute informants were also interviewed on the general theme of mathematics in their education and, in the case of the instructors, their current instructional positions, in order to answer the research question. The outline of these semi structured interviews can be found in Appendix D. Vocational instructors, in addition to learners, were chosen as interviewees from the focal site because they provide an acute insight into the meaning and especially the relevancy of mathematics to the learner's chosen career. There are some insights the learner can never provide. One of the goals of the interview design was to keep the interviews with the instructors comparable to the learners by including similar questions for both.

The semi-structured interviews with vocational instructors at the *Art Institute* yielded 12 digitally recorded interviews with representing various vocational categories such as Advertising, Animation, Fashion Design, Fashion Marketing, Interior Design, Culinary Arts, Graphic Design, Liberal Arts, Game Programming and Game Design. The outline of this study, the recruiting script and consent form for the instructor interviews were initially e-mailed to all the vocational instructors at the focal site. This yielded only four replies, indicating it would be extremely difficult to recruit instructors from all the vocations at the focal site using this scattershot approach. Further instructor interviewees were eventually selected by *snowball sampling*, which is a special non-probability method used when the desired sample characteristic is rare. While this technique dramatically lowered search time, it comes at the expense of introducing bias because the technique itself reduces the likelihood that the sample will represent a good cross section from the population of vocational instructors.

The interviews lasted approximately twenty minutes in length; they took place in the instructor's classroom during a break in class or in specialized interview rooms provided by the *Art Institute* and were digitally recorded for later transcription and analysis.

Recruitment of adult math learners for interview required a different approach. On the last day of the developmental math course, the study was introduced with a recruiting script and consent form and all the learners were invited to participate in an interview. Four learners responded to the request by returning the signed and dated consent form. These students were

then informed that they would receive an e-mail at the start of the next developmental math course, letting them know that they were selected for an interview and setting up a time and place for the interview. Ultimately these interviews took place in a specialized private interview rooms, they lasted approximately twenty minutes in length each and were digitally recorded for later transcription.

Descriptive Categories for Analysis

The interview transcripts of both adult math learners and vocational instructors at the *Art Institute* are coded based on the *Crossroads* principles as categories for analysis:

Crossroads Principle	Theme	Code
All learners should grow in their knowledge of mathematics while attending college.	The *Big Ideas* of math	BI
Learners should be taught mathematics that is meaningful and relevant	Meaningful and relevant mathematics instruction	MI
Developmental mathematics should be taught as a laboratory discipline.	Relevant constructivist projects	LD
The use of technology is an essential part of an up-to-date curriculum.	Technology in adult math learning	TI
Other	Miscellaneous	MT

The research analysis is based on the frequency of the categories for analysis in the transcripts of the semi-structured interviews with learners and vocational instructors. The construction of these categories for analysis, or codes, is not arbitrary, but based on the principles of the *Crossroads* report as shown above.

The Big Ideas of Math Theme	Code
Proportion	Pro
Number Sense	Nus
Measurement	Mmt
Variable	Var
Relations	Rel
Representation	Rep
Induction/Deduction	Idu
Balance	Bal

The first of these principles is *All learners should grow in their knowledge of mathematics while attending college* (BI). This theme is further detailed by the sub-themes of the *Big Ideas*. The second principle of *Crossroads* is that *Learners should be taught mathematics that is meaningful and relevant* (MI). In addition, these instructional themes were also sub-themed with the cognitive, behaviorist and constructivist instructional styles, such that:

Meaningful Instruction Sub Theme	Code

Cognitive	Cog
Constructivist	Con
Behaviorist	Beh

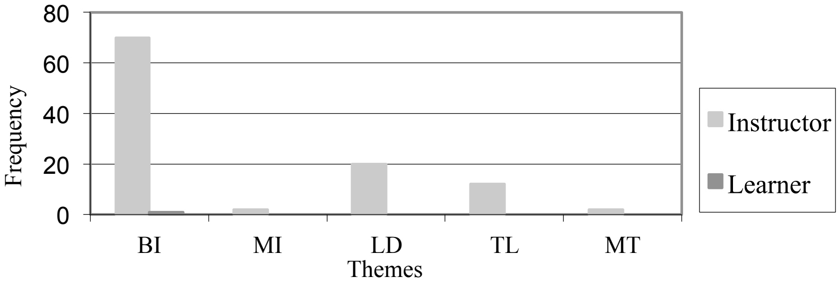
The third and fourth principles are *Mathematics should be taught as a laboratory discipline* (LD) and *The use of technology is an essential part of an up-to-date curriculum* (TL). The miscellaneous themes (MT) were reserved for meaningful learning and instruction themes that were *not* based on the *Crossroads report*. Finally, all of the above themes in meaningful mathematics learning were cross-coded with vocational and learner identities.

Informant	Code
Advertising Instructor	Adv
Animation Instructor	Anim
Fashion Design Instructor	FaDes
Fashion Marketing Instructor	FaMar
Interior Design1 Instructor	IntDes1
Interior Design2 Instructor	IntDes2
Culinary Arts Instructor	CulArt
Graphic Design Instructor	GrDes
Liberal Arts Instructor	LibArt
Game Programming Instructor	GaPrg
Game Design Instructor	GaDes
Learner 1	L1
Learner 2	L2
Learner 3	L3
Learner 4	L4

Finally, artifacts such as learners' projects, exercises and class observations, complete the data gathering. These were also used as a data in order to perform the analysis.

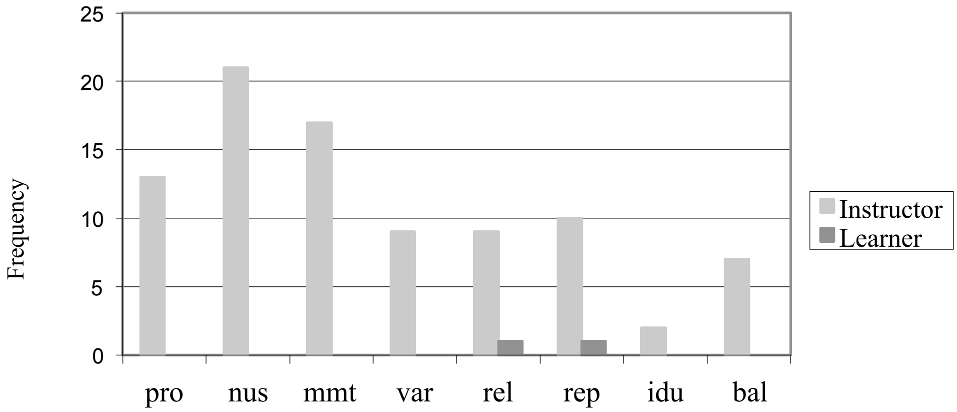
Results

Graph 1a shows there are approximately seventy instances of *all learners should grow in their knowledge of mathematics while attending college* themes in the 12 instructor interviews and less than five for the four learner interviews. This also contains references to project based learning themes and twelve references to technological co-themes within the primary theme. There are surprisingly small frequencies of themes combined with meaningful and relevant instruction. Overall this theme has a powerful resonance amongst the instructors, but less so amongst the learners.



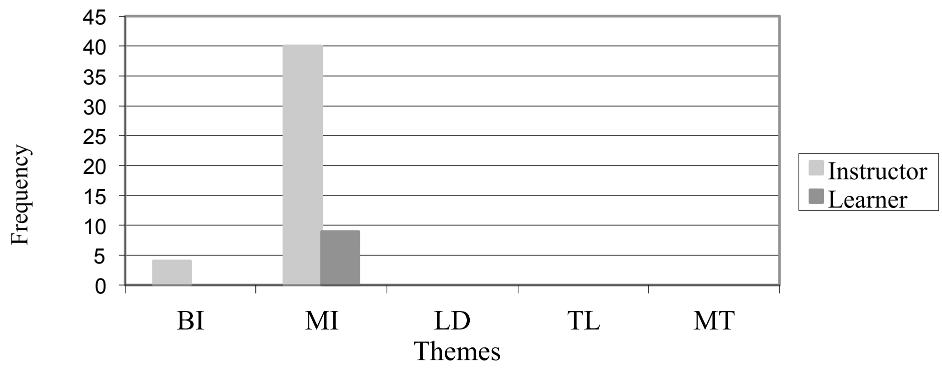
Graph 1a. Distribution of the principle all learners should grow in their knowledge of mathematics while attending college (code BI)

The Graph 1b shows the approximately seventy instances of the *all learners should grow in their knowledge of mathematics while attending college* (BI) themes in the 12 instructor interviews and four learner interviews broken down into the sub-themes of the *Big Ideas* of mathematics. The frequency shows a large tendency amongst instructors to themes of proportion, number sense and measurement, with considerable references to variable, relations, representation and balance. Learners are hardly represented in this category.



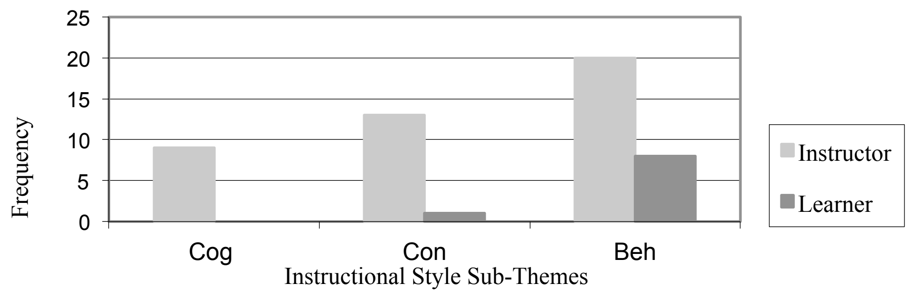
Graph 1b. Distribution of the sub-themes on the all learners should grow in their knowledge of mathematics while attending college

The Graph 2a shows there were approximately forty instances of the theme *all learners should be taught mathematics that is meaningful and relevant* in the 12 instructor interviews and less than ten for the four learner interviews. There were a surprisingly small frequency of co-themes in meaningful instruction from the *Big Ideas,* project learning and in technology.



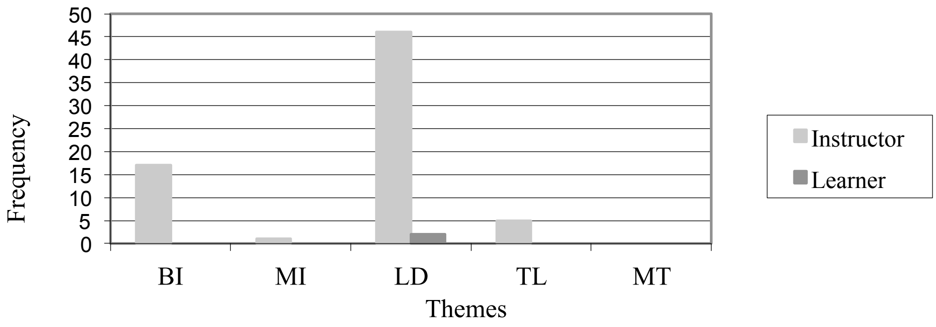
Graph 2a. Distribution of the principle all learners should be taught mathematics that is meaningful and relevant (code MI)

Graph 2b shows the approximately forty instances of *all learners should be taught mathematics that is meaningful and relevant* themes in the 12 instructor interviews and four learner interviews broken down into the instructional sub-themes. From instructor interviews, there appears to be a strong correlation between instructor view of meaningful instruction and the principles of *The Standards* and *Crossroads* reports. We can see from Table 2b that the adult developmental learners appear to derive much more mathematical meaning from behaviorist and cognitive instructional tasks involving step by step process, the linking previous concepts and the repetition of the *Big Ideas* in different contexts.



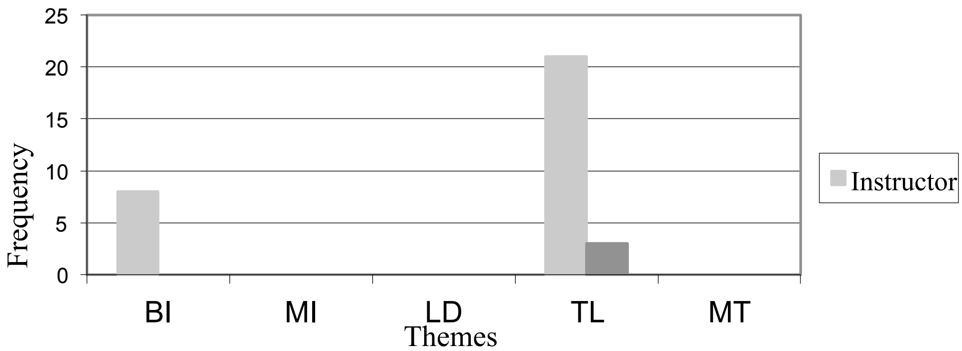
Graph 2b. Distribution of the sub-themes on the principle all learners should be taught mathematics that is meaningful and relevant

Graph 3 shows a high frequency of the principle**;** *developmental mathematics should be taught as a laboratory discipline*, with approximate forty-five references, with seventeen of these also referencing the *Big Ideas* and five also referencing technological co-themes.



Graph 3. Distribution of the principle developmental mathematics should be taught as a laboratory discipline (code LD)

Graph 4 shows the frequency of t*he use of technology is an essential part of an up-to-date curriculum* themes, with approximately twenty two references, with eight also co-referencing the *Big Ideas* of mathematics. These themes proved useful in generating relevant and meaningful projects and example problems.



Graph 4. Distribution of the principle the use of technology is an essential part of an up-to-date curriculum (code TL)

Limitations of the Results

The traditional perspective of research methods literature typically puts most of the emphasis on the role of the researcher in the interview process. Interviewers are purported to be "instruments" in the research process, and the researcher is encouraged to build rapport and trust with the interview subjects by being an attentive listener and having a "sympathetic understanding" of, and profound respect for, their thoughts, opinions, and perspectives (Angrosino, M. and Mays de Pérez, 2000). While some have warned about the potential dangers of over-rapport, such as the lack of objectivity on the part of the researcher, others have encouraged the establishment of some type of relationship between the interviewer.

Perhaps the most important development away from this traditional model of the interview in recent years has been the articulation of the constructivist approach to the interview. Constructivism emphasizes the dialogic nature of the interview and the mutuality of the research. In contrast to the traditional approach in which the interviewee is viewed as a repository of answers and the interview process itself is visualized as a conduit or pipeline of information that the researcher seeks, constructivism understands the interview as a meaning-

making experience and as a site for producing knowledge through the "active" collaboration of both interviewer and interviewee (Fontana, A. and Frey, J., 2000). The interview is no longer defined as a question-and-answer format, social scientific prospecting, or a search-and-discovery mission, but a "special performance" involving interviewer and interviewee both eliciting and representing an interpretive relationship of the world. Some may be suspicious of this journalistic and non-scientific approach, but we have to remember that the supposedly objective scientific approach to anthropology has been historically compromised (Burawoy, M., 1991).

Findings

From the analysis, came this set of findings:

- The vocational instructor interviews are liberally sprinkled with the constructivist learning and instruction principles of *Crossroads.*
- Alternatively, the learner interviews show a quantitative and qualitative tendency to an interactive, behaviourist, step-by-step instructional approach, with each step logically linked to its predecessor, resonates strongly with the adult learner informants.
- The use of repetition to create meaning in various contexts is a common theme in the instructor and adult learner interviews, "*I had to do the problems over and over to check my solution and this repetition made me get the concepts"*.
- Instruction presenting mathematics in visual, verbal, spatial and textual representations of meaning is an important theme in the vocational instructor interviews.
- The interview results in the miscellaneous themes and especially the artifact evidence the appendices; indicate that developmental learners show signs of cognitive overload on certain constructivist tasks.

Conclusions

The principles of constructivist math learning are strongly reflected in the math recollections of vocational instructors at the *Art Institute,* but not so much in the recollections of adult math learners. The vocational instructor interviews suggest a strong linkage between the principles of *Crossroads and The Standards* to relevance in specific vocational training. According to the interview themes, the *Big Ideas* of mathematics can be directly linked to relevant vocations, practices and ubiquitous software design tools such as *Illustrator, Photoshop* and *AutoCAD*.

In addition, the *repetition* of mathematical ideas in various contexts is a common theme in the learners' interviews. Likewise, learners in the Confucian Heritage Countries (CHC) are known to practice memorizing and repetition, which, if one equates memorizing with surface learning, brings into question the amount of meaningful learning that takes place. However in CHC memorizing is not synonymous with rote learning (Biggs, 1996). Repetition is carried in order to create meaning, or as a contextual response to the critical need to pass exams. As far as the learner in the CHC is concerned, memorizing is a means of becoming

thoroughly acquainted with the subject, to facilitate reflection and understanding. This same phenomenon may exist in the adult learner community.

The interview results in the miscellaneous themes and especially artifact evidence indicate that developmental learners show signs of cognitive overload on certain constructivist tasks. If a learner has acquired appropriate automated schemas, cognitive load will be low and substantial working memory resources are likely to be free (Sweller, 1994). In contrast, if the elements of material that require processing must each be considered as a discreet element in working memory because no schema is available, cognitive load will be high. Working memory may be entirely occupied in processing large numbers of individual elements. Secondly, the characteristics of the instructional material are important. Some material can be learned element by element, without relating one element to another. Learning multiplication of decimals is a good example. Each multiplication operation on a decimal number can be learned without reference to any other item in the schemas. Such material is low in element interactivity and low in intrinsic cognitive load. It imposes minimal demands on working memory.

Alternatively, situations where a number of elements must be considered simultaneously for the successful execution of a task are called high element interactivity tasks. A learner competent in elementary algebra will treat the distribution, c(a + b) as a single, automated schema requiring limited working memory resources. A novice who has just commenced learning algebra may need to treat each symbol and relations between symbols as individual, interacting elements, resulting in a working memory overload. These adult learners may have been previously accustomed to a traditional and rote approach to mathematics instruction. These developmental learners appear to derive more mathematical meaning from behaviorist tasks involving step-by-step processes; the linking of previous concepts, and the repetition of key ideas are effective approaches.

Finally, from the contradictions between learner and instructor perspectives, we must conclude that mathematics meaning is *subjective* and *individual*. The concept of *multiple representations of meaning*, rather than Gardner's lamely termed *multiple intelligences* (Gardner, 1983), avoids the controversial definition of *intelligence* and emphasizes the subjectivity of meaning.

Implications and Recommendations

This study has important implications for secondary and tertiary math instructors, academic directors, and principals. The resulting recommendation would be to limit cognitive load in developmental learners by utilizing carefully controlled and highly structured constructivist projects ensuring the concept or schema is in place before embarking on ambitious constructivist exercises and projects.

The learner survey and interview results show that an interactive, step-by-step, visual instructional approach, with each step logically linked to its predecessor may be a suitable approach to developmental mathematics. According to instructor interviews, developmental learners appear to derive mathematical meaning from visual and verbal approaches, which I have termed *Multiple Representations of Meaning.* Multiple meanings may be a more helpful concept than the concept of multiple intelligences (Gardner, 1983).

Another implication is that instructor-training programs might shift the emphasis from teaching universal concepts of objective meaning to those of subjective meaning. Courses for prospective instructors should provide an awareness of what research reveals about project

based learning, how we learn mathematics, models for effective learning, and an understanding of the power and limitations of the use of technology in the classroom.

According to *Crossroads,* further research is necessary to understand what works specifically in adult developmental mathematics. In particular, we need to understand more precisely which approaches do promote positive learning outcomes. Is it because of the material covered, the instructional methods used, challenges outside of the classroom such as financial or family constraints, or some combination of all of these factors?

This research is of a single case and can be expanded to multiple cases or extended over time with different instructors at the same focal site. These studies could then be scaled up to multiple focal sites and multiple time lines.

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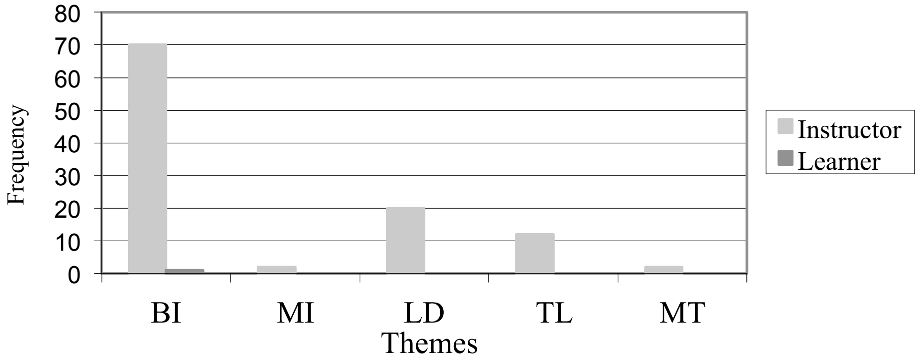
APPENDIX A. Results

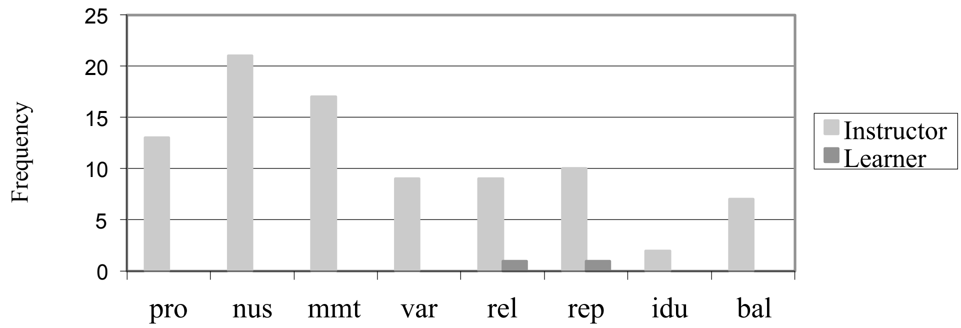
There are two distinct ways in which the results of the qualitative analysis of the adult learner and instructor interviews may be reported. One way is to look at the data in a quantitative way. The interview transcripts provide the opportunity to count the frequencies in which each of the codes was attributed to learners and instructor transcripts. Another method of analysis tends to the qualitative, being based on the analysis of actual responses by interviewees. The following graphs show how these meaningful themes were quantitatively distributed among the transcripts of the learners and instructor interviews. In contrast, the quote tables apply a qualitative lens to the interview questions.



Graph 1a. Distribution of the principle all learners should grow in their knowledge of mathematics while attending college (code BI)

IntDes1 Code: BI,LD Sub:pro	*"I'm making something little and dealing with scale, proportions and perspective all the time"*
IntDes1 Code: BI,LD Sub:mmt, bal	*"I get my learners to draw a circle and divide it into 12 equal parts using just a ruler, protractor and compasses"*
AuPro Code: BI,LD Sub:pro, nus, rel	*"This distance ratios on a guitar fret board relate to pitch and the harmonics relate to factors of those ratios"*

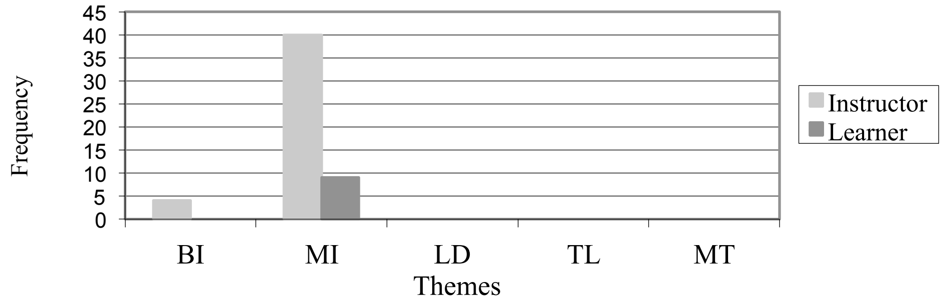
Table 1a:Transcript examples of the principle all learners should grow in their knowledge of mathematics while attending college (code BI)



Graph 1b. Distribution of the sub-themes on the all learners should grow in their knowledge of mathematics while attending college

FaDes Code: BI,LD Sub:nus	*"I have to add four fractional measurements"*
FaDes Code: BI,LD Sub:mmt, pro	*"I also have to scale the measurements from medium down to small sizes and up to large sizes"*
FaDes Code: BI Sub:mmt, var, rel	*"I know a lot of them cannot do a circumference from a radius"*

Table 1b. Example transcripts of the sub-themes on principle all learners should grow in their knowledge of mathematics while attending college



Graph 2a. Distribution of the principle all learners should be taught mathematics that is meaningful and relevant (code MI)

CulArt Code: MI,LD Sub:	*"This is a technical art college so we need to stress both skills. I would bring in some graphical or visual elements. Also steer away from just formulas and stress the why behind the problem. Like science, do the experiments and show them if you can"*
GraDes Code: MI Sub:	*"It was completely dependent on the teacher. I was either completely successful or not successful at all"*
IntDes2 Code: BI Sub:	*"Not so much, this is how you are, but lets fix this. A little less of writing it off as just a weakness. I see a difference now how my child is taught, we are not going to write you off, you can do it, we want you to do it! Now she is getting A's and B's"*

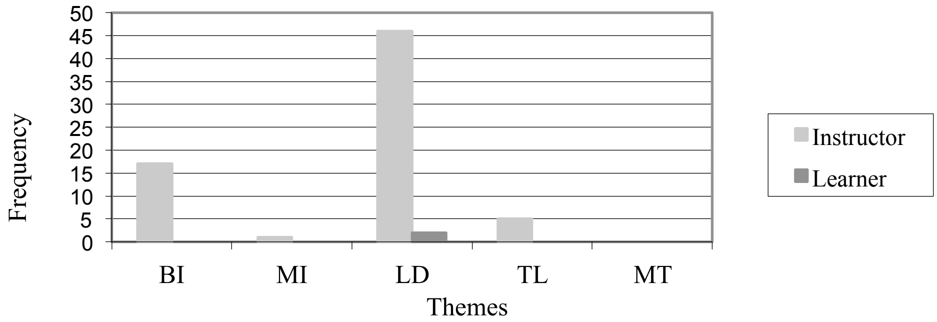
Table 2a. Example transcripts of the principle all learners should be taught mathematics that is meaningful and relevant

Graph 2b. Distribution of the sub-themes on the principle all learners should be taught mathematics that is meaningful and relevant

Lrn2 Code: MI Sub:cog	*"The class was good for me because you go over the easy stuff first, get that solid and than move on to the next step, instead of jumping right into algebra. I mean, I was screwing up with division and I have division down now. It was much better"*

Lrn2 Code: MI Sub:cog	*"Moving gradually step by step definitely helps"*
Lrn4 Code: MI Sub:con	*"The teaching style was a little different here, a little more flow and intuition"*
GaPro Code: MI,LDBI Sub:	*"95% of people think visually. I would have them plotting Cartesian graphs and making a picture. An equation can make a picture. Like with my sister in-law, x cubed doesn't mean anything, but an S on its side might have more meaning"*
GraDes Code: MI Sub:	*"Working lots of problems, project them on to the wall, working them through step by step"*
FaMar Code: BI Sub:	*"And I always repeat it over and over so they get it"*

Table 2b. Example transcripts of the sub-themes on the principle all learners should be taught mathematics that is meaningful and relevant

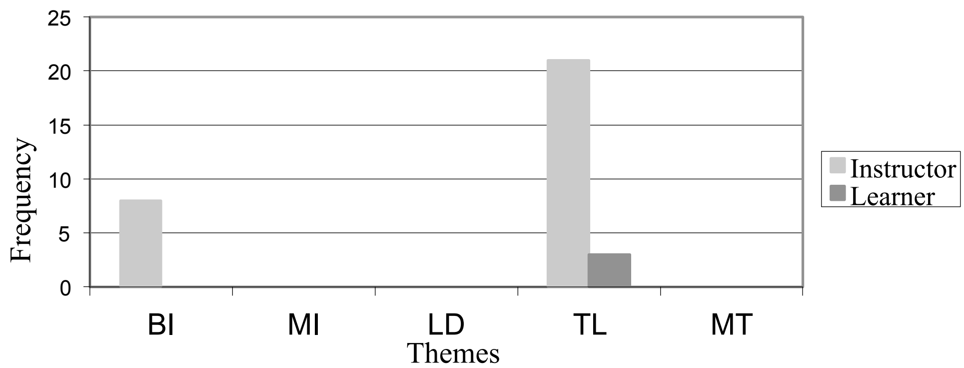


Graph 3. Distribution of the principle developmental mathematics should be taught as a laboratory discipline (code LD)

FaDes Code: LD Sub:	*"I love figuring out the geometric shapes. I would have been great at math if I was designing cargo pockets!"*

FaDes Code: LD,BI Sub:mmt,var	*"With a circle skirt we have to do a radius at the top for the waist and a radius at the bottom for the hem. Anything in the round, we also have to do funnel shaped sleeves"*
AuPro Code: LD Sub:pro, rel	*"Can you create a ratio? What is a ratio? We went though that together and he realized 120 BPM is twice as fast as 60 BPM. We were looking at rates and time. If I have 2 beats per second how many BPM do I have?"*

Table 3. Transcript examples of the principle developmental mathematics should be taught as a laboratory discipline (code LD)

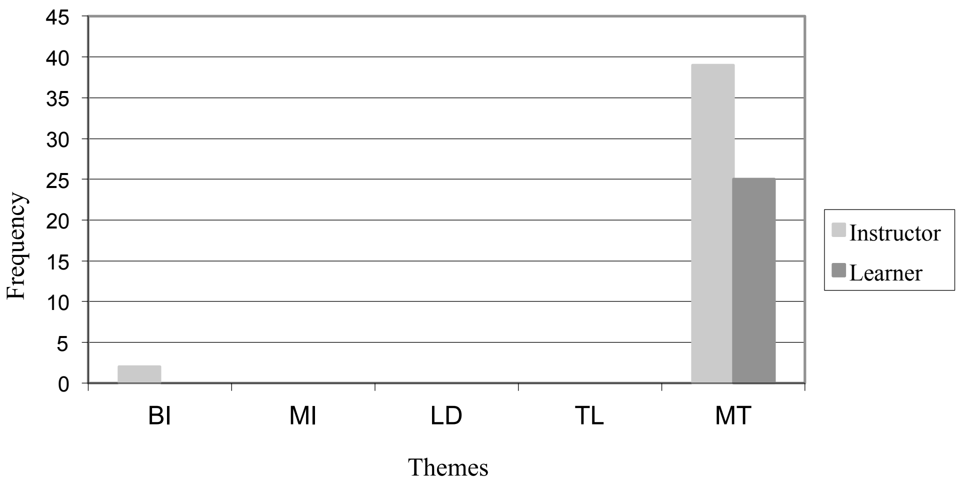


Graph 4. Distribution of the principle the use of technology is an essential part of an up-to-date curriculum (code TL)

Adv Code: TL Sub:	*"Sure. I show them a lot of ads in magazines. And of course they hadn't seen them before, because nobody under forty reads a newspaper. So we investigate how much it is to go on Facebook or YouTube or whatever"*
Adv Code: TL Sub:	*"One of the projects is that class is to find a location for their business. They have to go online and find the cost for rent of the place their business is going to be"*
FaMar Code: TL,BI Sub: Lrn4	*"Your students have to memorize the basic formulas, then they have to apply them to Excel"*

Code: TL Sub:	*"I'm looking at graphing and how the x and y coordinates of Photoshop fit into it, like position"*
Lrn4 Code: TL Sub:	*"I would just paint over the basic forms. Once I stated doing certain models that requires a high degree of symmetry, you have to mirror it with the origin over here with a certain number of grid points"*
Lrn4 Code: TL Sub:	*"No, Photoshop. I use Illustrator sporadically. In logo design, I might create a stencil in Illustrator and shoot that to use in Photoshop. I don't use Illustrator nearly as much as I use Photoshop"*

Table 4. Transcript examples of the principle the use of technology is an essential part of an up-to-date curriculum (code TL)



Graph 5. Distribution of miscellaneous learning and Instruction themes(code MT)

IntDes1 Code: MT Sub:	*"Math just seemed to make sense to me, part of that was because I was dyslexic. I had to do the problems over and over to check my solution and this repetition made me get the concepts"*
AuPro Code: MT,LD Sub:	*"He was like…. explosions going off in his head! Frankly, I don't think he understood my lecture until that moment [of doing a project]"*

AuPro Code: MT Sub:	*"At this point they don't have the skills to research their own materials"*
IntDes1 Code: MT,BI Sub:	*"I had to do the problems over and over to check my solution and this repetition made me get the concepts. When it got to balancing equations it was a piece of cake"*
LibArt Code: MI Sub:Be	*"Working lots of problems, project them on to the wall, working them through step by step"*
FaMar Code: MI Sub:Be	*"And I always repeat it over and over so they get ii. My challenge with math was, they wrote it on the board and they said it, but I missed it! It was like, Oh, what do I do?*

Table 5. Transcripts of miscellaneous learning and instruction themes (code MT)

CulArt Code: MI,LD Sub:	*"This is a technical art college so we need to stress both skills. I would bring in some graphical or visual elements. Also steer away from just formulas and stress the why behind the problem. Like science, do the experiments and show them if you can"*
IntDes2 Code: BI,TL Sub:	*"Later they get into the whole three dimensional thing in AutoCAD. It is important that their brain can see something from one view, but it can also be visualized from another perspective. Looking at a space from different angles. Imagine it, without having to draw it first"*
Anim Code: MT Sub:	*"Its probably the complexity of the language and that I'm a very visual person"*

Table 6. Transcripts of Visual, Verbal and Spatial Representations of Meaning

Appendix B: Interview Results

Results of the themes on the principle *all learners should grow in their knowledge of mathematics while attending college* (BI)

	BI	MI	LD	TL	MT
Adv	2	0	2	1	0
Anim	8	0	3	1	0
FaDes	7	0	3	0	0
AuPro	5	0	3	1	0
FaMar	6	0	1	1	0
IntDes1	9	0	1	0	1
IntDes2	11	0	0	3	1
CulArt	5	0	2	0	0
GrDes	6	0	1	1	0
LibArt	1	1	0	0	0
GaPrg	2	1	0	0	0
GaDes	8	0	4	4	0
L1	0	0	0	0	0
L2	0	0	0	0	0
L3	0	0	0	0	0
L4	1	0	0	0	0

Sub-Themes on the *Big Ideas* of Math

	pro	nus	mmt	var	rel	rep	idu	bal
Adv	0	0	0	2	0	0	0	0
Anim	3	3	2	1	1	1	0	0
FaDes	1	4	5	0	1	0	0	0
AuPro	2	2	0	1	2	1	0	0
FaMar	0	3	0	1	1	0	0	3
IntDes1	2	2	2	0	1	0	0	1
IntDes2	1	3	5	0	1	1	0	0
CulArt	1	1	0	3	0	0	1	1
GrDes	2	1	3	0	0	0	0	1
LibArt	0	0	0	0	0	1	1	0
GaPrg	0	1	0	0	1	1	0	1
GaDes	1	1	0	1	1	5	0	0
L1	0	0	0	0	0	0	0	0
L2	0	0	0	0	0	0	0	0
L3	0	0	0	0	0	0	0	0
L4	0	0	0	0	1	1	0	0

Themes on *all learners should be taught mathematics that is meaningful and relevant* (MI)

	BI	MI	LD	TL	MT		Cog	Con	Beh
Adv	0	2	0	0	0		0	0	2
Anim	0	2	0	0	0		0	2	0
FaDes	0	0	0	0	0		0	0	0
AuPro	0	2	0	0	0		1	1	0
FaMar	0	5	0	0	0		1	0	4
IntDes1	0	2	0	0	0		1	1	1
IntDes2	0	4	0	0	0		1	1	2
CulArt	0	5	0	0	0		1	2	2
GrDes	0	5	0	0	0		1	2	3
LibArt	1	7	0	0	0		1	1	4
GaPrg	3	5	0	0	0		2	2	1
GaDes	0	1	0	0	0		0	1	1
L1	0	0	0	0	0		0	0	0
L2	0	3	0	0	0		0	1	2
L3	0	4	0	0	0		0	0	4
L4	0	2	0	0	0		0	0	2

Mathematics must be taught as a laboratory discipline (LD)

	BI	MI	LD	TL	MT
Adv	1	0	6	2	0
Anim	2	0	6	0	0
FaDes	6	0	9	1	0
AuPro	3	0	4	1	0
FaMar	0	0	2	0	0
IntDes1	1	0	5	0	0
IntDes2	0	0	2	0	0
GrDes	2	1	5	0	0
CulArt	0	0	4	0	0
LibArt	0	0	1	0	0
GaPrg	0	0	0	0	0
GaDes	2	0	2	1	0
L1	0	0	0	0	0
L2	0	0	1	0	0
L3	0	0	0	0	0

L4	0	0	1	0	0

The use of technology is an essential part of an up-to-date curriculum (TL)

	BI	ML	LD	TL	MT
Adv	1	0	0	4	0
Anim	0	0	0	1	0
FaDes	0	0	0	1	0
AuPro	0	0	0	4	0
FaMar	0	0	0	2	0
IntDes1	0	0	0	1	0
IntDes2	1	0	0	1	0
GrDes	2	0	0	1	0
CulArt	0	0	0	0	0
LibArt	0	0	0	0	0
GaPrg	1	0	0	3	0
GaDes	3	0	0	3	0
L1	0	0	0	0	0
L2	0	0	0	0	0
L3	0	0	0	0	0
L4	0	0	0	3	0

APPENDIX C: Observation and Participation in an Adult Developmental Tutoring Session

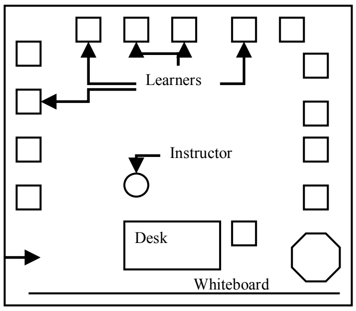
Pre-Observation

This is the classroom with the huge arched windows. As I entered the room, the instructor, who was hosting the tutoring session, was grading papers. 2 learners worked on their *College Algebra* homework (I has asked what they were working on).

I noted two learners from the previous class who were intently staring out of the huge window onto the street below. They had noticed that some of the simple looking transactions being played out in crowded streets below were, in fact covers for drug deals. We talked for a while about how animators were observers. The two animators disappeared into the streets.

Physical Description

This horseshoe arrangement allows many tutors to easily access each learner's work.



Artifacts: A student tutor-tutoring list. Many of my learners have complained of poor tutoring from student tutors. Perhaps more training for the tutors?

Narration of Events

As I entered the room, the instructor, who was hosting the tutoring session, was grading papers. 2 learners worked on their *College Algebra* homework (I has asked what they were working on). The instructor, who had an Italian background, began discussing Rosetta Stone (language learning software) with a learner who wanted to learn Chinese.

Exercise: simplify $t + \frac{1}{4}s - 6t + \frac{3}{5}s$

Learner: I dont get the $\frac{1}{4}s + \frac{3}{5}s$ part

Researcher: First chose the similar terms you can combine

Learner: t and $6t$

Researcher: ok Lets combine the t's, thats the easy part

Learner: $t - 6t = -5t$

Researcher: Good. Now lets do the s terms: $\frac{1}{4}s + \frac{3}{5}s$

Researcher: You can't combine these right now, as they have a different denominator.

Researcher: what would be a suitable common denominator for these terms?

Learner: how about 20?

Researcher: Ok, lets see what that looks like $\frac{?}{20}s + \frac{?}{20}s$

Researcher: How much bigger is 20 than 4?

Learner: 5 times as big

Researcher: 5 times good! To make the fraction the same, we must also multiply the numerator by 5

Learner: $\frac{5 \times 1}{20}s + \frac{?}{20}s$

Researcher: Lets do the other part. how much bigger is 20 than 5?

Learner: 4 times as big

Researcher: 4 times ok! To make the fraction the same we must also multiply the numerator by 4

Learner: $\frac{5}{20}s + \frac{3 \times 4}{20}s = \frac{5}{20}s + \frac{12}{20}s$

Learner: so thats $\frac{17}{40}s$ right?

Researcher: No. The common denominator stays the same. You only need to add the numerators together

Learner: So its $\frac{17}{20}s$

Researcher: Thats right. So what is the final simplification?

Learner: $-5t + \frac{17}{20}s$

Researcher: Thats right. We have given it a haircut.

Other learners are beginning to drift in for the 6 o'clock *College Algebra* class. It's time to go.

APPENDIX D: Semi Structured Vocational Instructor and Adult Learner Interview Questions

Your own math education

Looking back on your own education, did you experience an interest and engagement with Math? If so, ask questions 1 to 4. If not ask question 4 to 8.

1. What was it that sparked your interest?
2. Has this continued to be your motivation, or have any other factors emerged either during or since your school days?
3. Did your engagement with Math ever falter? If so, when and why and how did you regain it?
4. At school did you fully appreciate the meaning and relevance of Math?
5. What hampered/promoted your own Math learning?
6. When did your math education cease to engage you and why?
7. What could have been changed that would have improved your experience and made Math more relevant and meaningful for you?
8. Have you been able to improve your understanding of Math since leaving school? If so, when and how?

Math in your experience as a vocational instructor

9. Are there any elements of Math used in your formal curriculum? If so, what are they and how are they used?
10. Do you think your curriculum would benefit from additional Math? If so, what form would you like them to take?

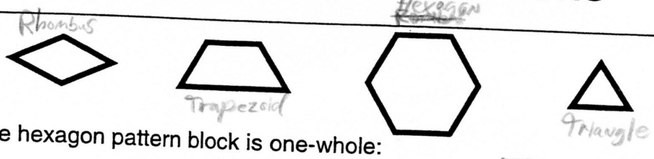
Your own opinions on the Meaning and Relevance of Math in Adult Education

11. Your own opinion or comment on any aspect of this subject that may not have been covered by this interview would be of value:

APPENDIX E: Completed Constructivist Learning Exercises

Excellent [redacted]

PATTERN BLOCK FRACTIONS



1. If the hexagon pattern block is one-whole:
   a. What is the value of a trapezoid? Half
   b. What is the value of a rhombus? 1/3
   c. Write an addition statement that shows that a relationship between the triangle and the rhombus. △ + △ = ◇
2. If the rhombus is one-whole:
   a. What is the value of a trapezoid? $1\frac{1}{2}$
   b. What is the value of a triangle? ½
   c. Write a subtraction statement that shows a relationship between the triangle, trapezoids, and rhombi. △ − ⏢ = ◇ note negative
3. If the trapezoid is one-whole:
   a. What is the value of the triangle? ⅓
   b. What is the value of the rhombus? 2/3
   c. Write a multiplication statement that shows a relationship between the rhombus and the hexagon. 3 × ◇ = ⬡
4. If the hexagon is one-whole:
   a. What is the value of the sum of the trapezoid and a triangle? a) 4/6 3 Triangle to a trapezoid
   b. What is the value of the sum of the rhombus and a trapezoid? 5/6
   c. Write a division statement that shows a relationship between the triangle and the trapezoid. △ ÷ ⏢ = 3 → 1/3

UCLA Math Programs for Teachers/LUCIMATH Project
Fraction Concepts

FRACT1A – PP6

Fundamentals of Mathematics [redacted]

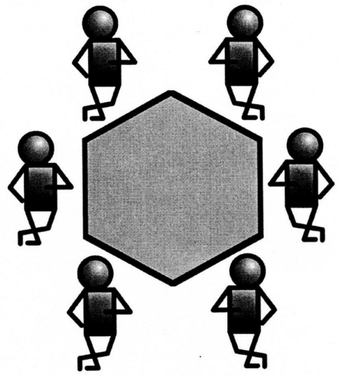
The Hexagonal Table Problem

In the Square Tables Problem you figured out the number of people who could sit in terms of the number of tables that were available.

What if instead of squares, the tables were hexagons?

Question 1: How many people can sit if there are 2, 3, or 4 tables?

2 tables = 12 people
3 tables = 18 people
4 tables = 24 people



Question 2: What pattern do you see? Describe the pattern in words:

Add 6 people for every table added

Let *T* represent the number of tables. Express the number of people who can sit in terms of *T*.

$P = 6T$

Question 3: Use the expression you just wrote to figure out how many people can sit if there are 8 tables, 10 tables, and 100 tables.

~~[illegible]~~ $P = 48$
$P = 60$
$P = 600$

Question 4: How many tables do you need for 90 people?

15 tables
$6\overline{)90}$

1

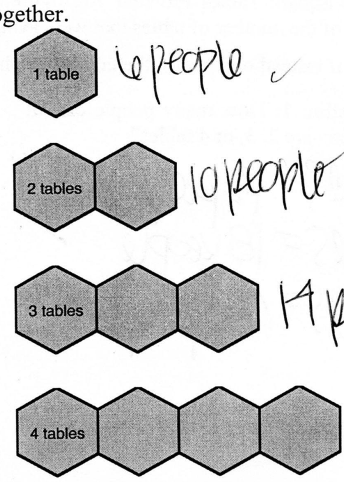
Thanks to Mara Landers

Fundamentals of Mathematics [redacted]

The Hexagonal Table Problem: Part 2

The situation: Your guests push the tables together.

Question 5: How many people can sit at each table in the picture at the right?



6 people ✓

10 people ✓

14 people ✓

18 people

Question 6: *Without drawing the tables*, figure out how many people can sit when 10 tables are pushed together. How did you figure this out?

$T = 10$

$P = 4T + 2$

10 tables = 42 people

Question 7: *Without drawing the tables*, figure out how many people can sit when 20 tables are pushed together. How did you figure this out?

$T = 20$

$4 + 20 + 2 = 82$ people ✓

Question 8: How many people can sit at *T* tables?

$P = 4T + 2$
$-2 \quad\;\; -2$

$\frac{P-2}{4} = \frac{4T}{4}$

$P - \frac{2}{4} = T$ ✓

2

Thanks to Mara Landers

APPENDIX F: Example Discovery Learning Projects

[redacted]

Mr. Glasser

9/23/09

Final Project

Question #1.

You're doing some manual film editing and you have three strips of mm film to clip together. Keeping in mind that 32 frames equal a second of animation, measure the three strips and solve the movies collected length if each 1/16 of an inch is 32 frames.

7in

4in

6in

7 + 4 + 6 = 17in

1/16 = 1 Second

60 Seconds = 1min

17 x 16 = 272 ÷ 60 = 4.53

in. seconds

OR 60 x 4 = 240

272 − 240 = 32

4min 32se

Answer: 4 min. 32 Seconds

OR 4.53

Question #2.

You have a project due in 60 days and progress is measured in percentages at this job. It is 50 days in from the start date, what percentage of work should be finished?

x/100=50/60

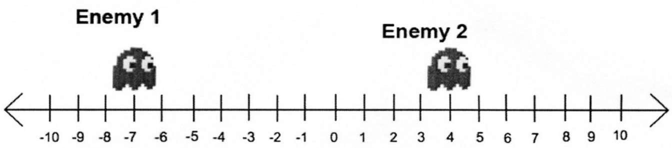
$\frac{x}{100} = \frac{50}{60}$ ×1.6 ÷1.6

50 x 1.6 = 80

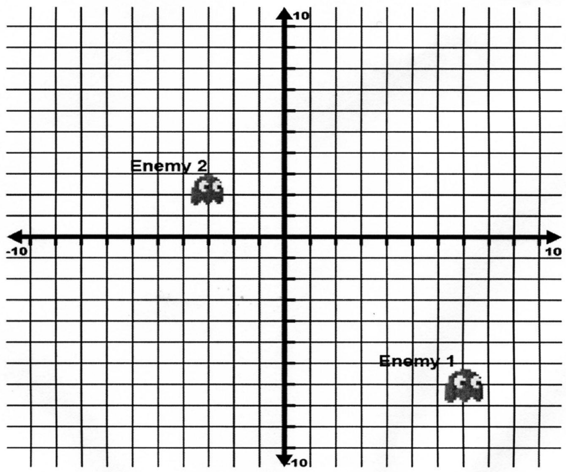
100 ÷ 60 = 1.6

Answer: 80%

[redacted]
9/23/09



1. What is the Distance Between Enemy1 and Enemy2?
2. James is designing a 2d Sidescrolling game. But he needs to create a level on a [30] [400] grid with 64 x 64 tiles. How many tiles will he need?



3. What are the X, Y coordinates for Enemy 1 and 2?

Name: [redacted]

Date: 09/23/09

Final Project: F. of Math

Optical Disc capacity comparison for Console games of yesteryear and today.

Legend-----------------------------

KB (Kilobyte)

MB (Megabytes)

GB (Gigabytes)

Playstaion One: CD-ROM = 700 MB

Playstation 2: DVD-ROM = 4.7 GB

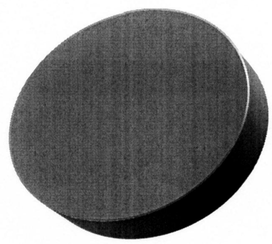
Xbox: DVD-ROM = 4.7/8.5 GB

Gamecube: DVD-ROM = 1.5 GB

Wii: DVD-ROM = 4.7 GB

Xbox360: DVD-ROM = 8.5 GB

PS3: Blu-Ray = 25/50 GB



1.) How much a DVD-ROM (4.7) in percent can it go in a Blu-Ray Disc (single layer 25GB)?

2.) How many CD-ROMs (700 MB) can you fit in a DVD-ROM (8.5 GB)?

3.) What is the percent of a Gamecube disc (1.5 GB) of a Wii Disc (4.7GB)?

APPENDIX G: Discovery Learning Projects Showing Signs of Cognitive Overload

Die Hard with a Vengence (1995)

The clip starts with John's Zues in the park opening a laptop. A riddle must be answerd to defuse a bomb.

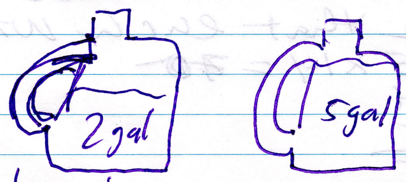
Exactly 4 gallons of water must be placed on a scale to defuse the bomb using only a gallon bottle & a 3 gallon bottle for measuring. How can this be accomplished.

(1) How much does the bottle weigh

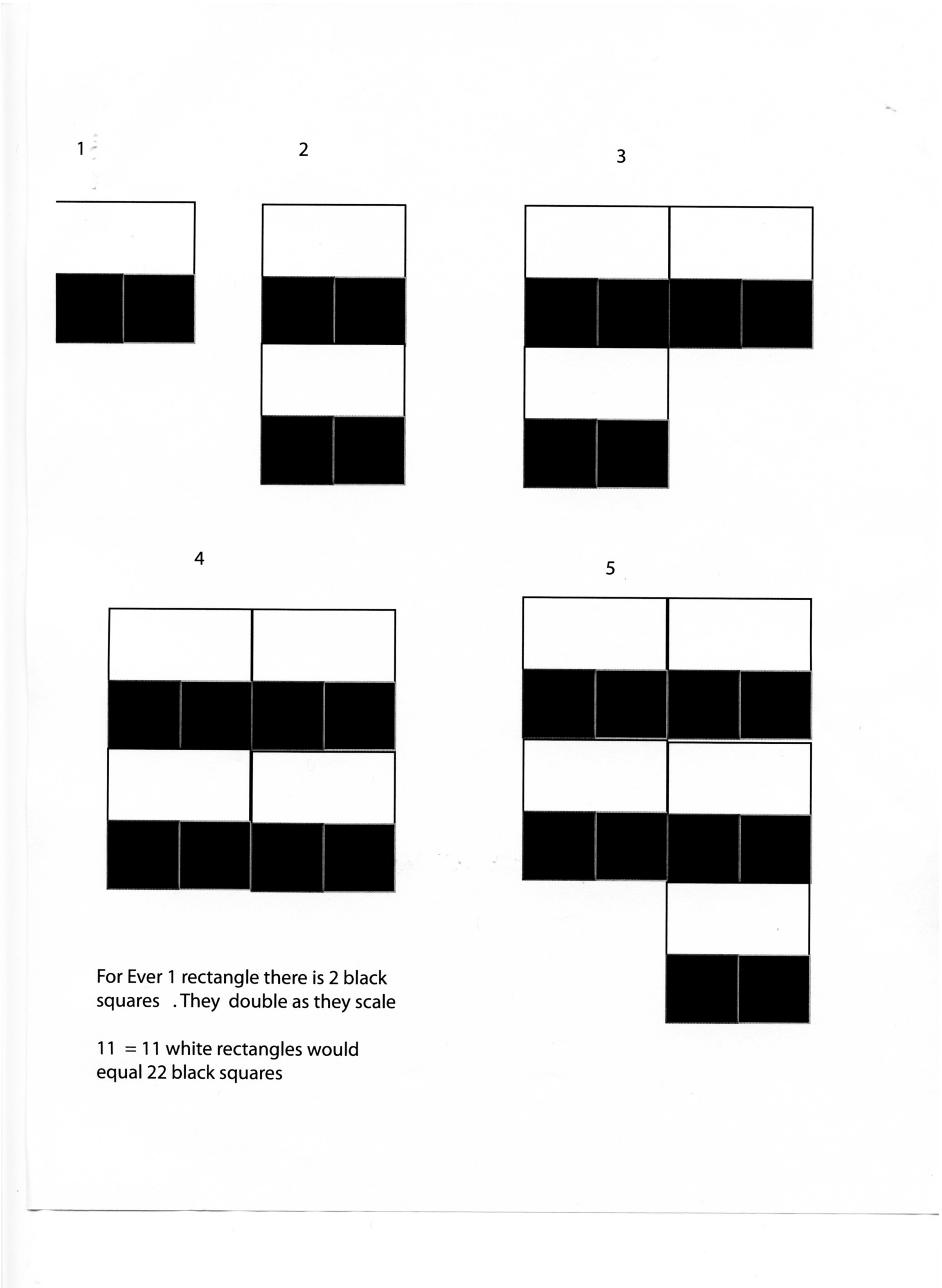
(2) How long does it take to fill the bottles

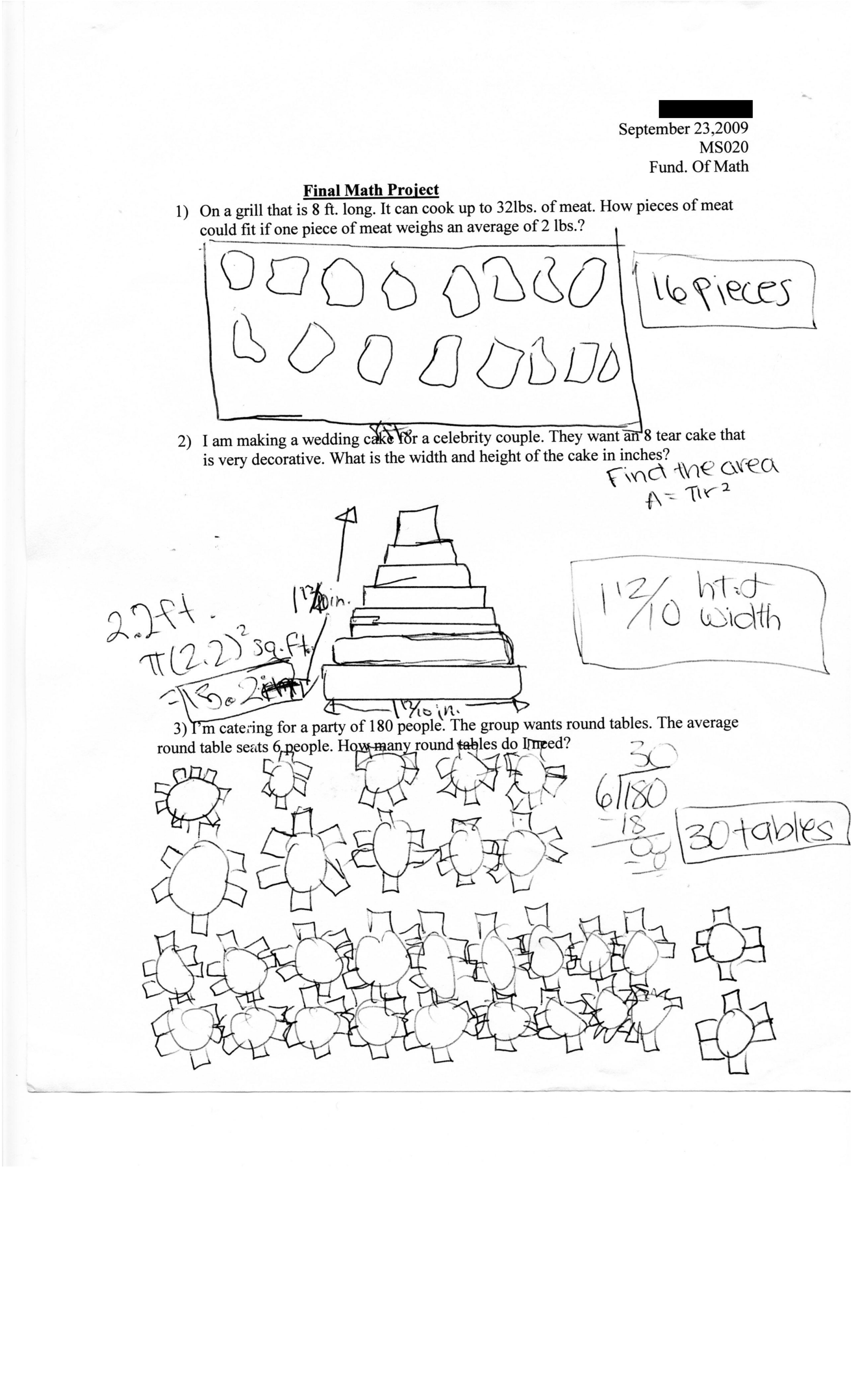
Exactly 2 gallons, leaving exactly 1 gallon of empty space.

If you have a full 5 gallons ~~hours~~ & you pull 1 gallon out of 5 gallons you have exactly 4 gallons.



leaving 1 gallon of empty space


1
2
3
4
5
For Ever 1 rectangle there is 2 black squares . They double as they scale
11 = 11 white rectangles would equal 22 black squares



[redacted]
September 23,2009
MS020
Fund. Of Math

Final Math Project

1) On a grill that is 8 ft. long. It can cook up to 32lbs. of meat. How pieces of meat could fit if one piece of meat weighs an average of 2 lbs.?

16 pieces

2) I am making a wedding cake for a celebrity couple. They want an 8 tear cake that is very decorative. What is the width and height of the cake in inches?

Find the area
$A = \pi r^2$

2.2ft.
$\pi(2.2)^2$ sq.ft.
$= 15.2$

$1\frac{12}{10}$ in.

$1\frac{12}{10}$ in.

$1\frac{12}{10}$ hight
width

3) I'm catering for a party of 180 people. The group wants round tables. The average round table seats 6 people. How many round tables do I need?

$6\overline{)180}$ = 30

30 tables